



Long-term PCM heat storage for a solar space heating and domestic hot water combisystem

Fan, Jianhua; Furbo, Simon; Wang, Zhifeng; Englmaier, Gerald

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Technical University of Denmark

Department of Civil Engineering

Section for Building Energy

Ass. Prof. Jianhua Fan jif@byg.dtu.dk

Ass. Prof. Simon Furbo



Chinese Academy of Sciences

Institute of Electrical Engineering

Solar Energy Laboratory

Prof. Zhifeng Wang



Gerald Englmaier, MSc.

Start of PhD-study: 01.05.2015

gereng@byg.dtu.dk

www.byg.dtu.dk

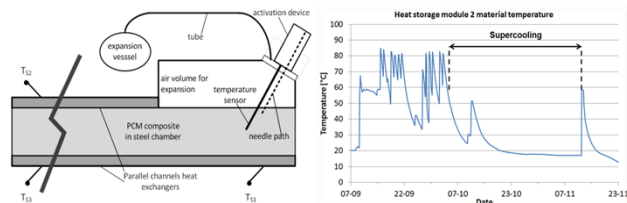
Long-term PCM heat storage for a solar space heating and domestic hot water combisystem

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\rho c_p} \frac{\partial^2 T}{\partial x^2} + \alpha \int_0^{\infty} \Theta \delta e^{-\eta x} = -I$$

$$\sum_{i=1}^n \frac{1}{x_i} = \frac{1}{2.7182818284} \approx 0.367879441$$

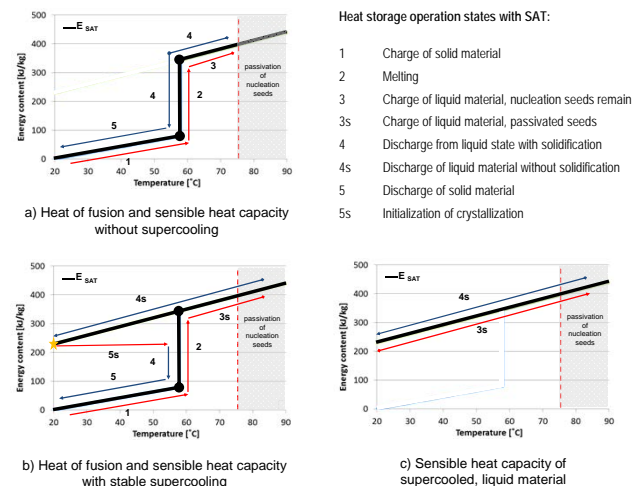
Background: Due to the mismatch of solar energy resources and the demand of thermal household services, long-term storage of heat is essential for an innovative solar heating system that covers the heat demand with a high solar fraction in the range of 80%-100%. Therefore a concept for a novel compact seasonal heat store based on stable supercooling of a phase change material (PCM) has been defined in previous research activities at DTU [1].

Material: Sodium Acetate Trihydrate (SAT) is a salt hydrate with a melting point of 58 °C and a relatively high latent heat of fusion (264 kJ kg⁻¹). It can be used as PCM in heat storage applications. Additives are used to stabilize the SAT, optimize or enhance the material properties and ensure cycling stability [2]. SAT can be used for long term heat storage by utilizing its ability to supercool stable to ambient temperature while heat of fusion is preserved.



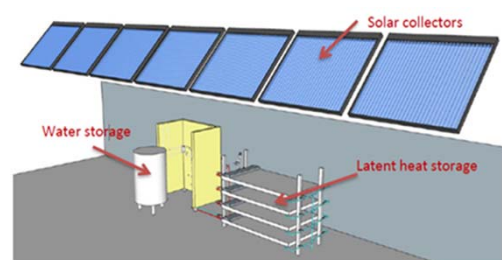
Heat storage units: Flat units were constructed by the Danish company Nilan A/S with an internal height of 5 cm, resulting in a 150 l enclosed material chamber (left figure). Laboratory tests were conducted by Dannemand et al. [3]. During tests with a solar collector field as heat source [4] modules were frequently heated up to a temperature above 77 °C, afterwards stable supercooling was achieved for several months before solidification was initiated by seed crystal injection (right figure).

Functionality: With SAT composites three different storage principles (a-c) can be utilized for combined short-term and long-term storage of heat:



References:

- [1] Long term thermal energy storage with stable supercooled sodium acetate trihydrate, Mark Dannemand, Jørgen M. Schultz, Jakob Berg Johansen, Simon Furbo. Applied Thermal Engineering (91), 2015
- [2] Experimental investigations on heat content of supercooled sodium acetate trihydrate by a simple heat loss method, Weiqiang Kong, Mark Dannemand, Jakob Berg Johansen, Jianhua Fan, Janne Dragsted, Gerald Englmaier, Simon Furbo. Solar Energy, vol. 139, pp. 249-257, 2016
- [3] Experimental investigations on prototype heat storage units utilizing stable supercooling of sodium acetate trihydrate mixtures, Mark Dannemand, Janne Dragsted, Jianhua Fan, Jakob Berg Johansen, Weiqiang Kong, Simon Furbo. Applied Energy, vol. 169, pp. 72-80, 2016
- [4] Testing of PCM heat storage modules with solar collectors as heat source, Gerald Englmaier, Mark Dannemand, Jakob Berg Johansen, Weiqiang Kong, Janne Dragsted, Simon Furbo, Jianhua Fan. International Conference on Solar Heating and Cooling for Buildings and Industry, Energy Procedia, vol. 91, pp. 138-144, 2016

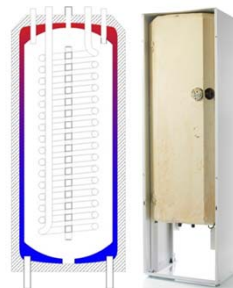


Demonstration system: A segmented PCM heat storage was formed by 4 individual flat units, each containing about 200 kg of SAT composites. The units were charged with solar heat supplied by 22.4 m² of evacuated tubular collectors and discharged to a 735 l water storage in periods with shortage of solar energy. On sunny days, the water storage was charged directly by the collector array. Calculated demand on hot water and space heating for a Passive House in Danish climate was drawn off at the water storage. System operation was realized via a LabVIEW control program.



Novel, economic heat storage unit:

- Hypothesis A: It will be possible to design an economic heat storage unit based on standard components from industry.
- Hypothesis B: The heat transfer will be sufficient for domestic hot water and space heating supply by combined usage of a mantle and a spiral heat exchanger.



Storage specifications:

PCM filling:	200 kg
Inner tank diameter:	0.45 m
Inner tank height:	1.20 m
Outer tank diameter:	0.50 m
Outer tank height:	1.25 m
Heat transfer area :	2.95 m ²
PCM volume :	<150 l
Mantle volume:	54.6 l
Steel tank mass:	140.8 kg

Work flow:

- ✓ Successful system demonstration and automated system control
- ✓ Tests on operation behavior
- ✓ Periodic system performance analysis
- ✓ Economic heat storage design
- System simulation (collaboration with TU Graz) for optimized component sizing and system design
- Participation in IEA Task 58, Annex 33

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